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GB 2271893 A GB 2253099 A GB 2242795 A
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(54) **Power controller of an induction motor**

(57) A power controller of an induction motor C, L1, L2 with a main winding L1 and with an auxiliary winding L2 provides power control of the motor by means of a recurring digital word, such as from a ring counter 2. The auxiliary winding L2 has tappings N1, N2 and different power levels of the motor are set by the connection of the auxiliary winding or one of its sub-windings by means of triacs T1 - T4. Firstly a coarse adjustment of the power to be output by the motor is effected by the selection of a specified power level and at the same time for the fine adjustment a recurring digital m-bit keying pattern is generated by the ring counter 2 so that the motor is operated alternately with the set power level and with a next higher or next lower power level. This permits automatic power regulation. A microprocessor 3 carries out the coarse adjustment via a drive circuit 1 and at the same time generates the m-bit keying pattern which is stored in the ring counter 2. In alternative embodiments (Figs. 3 and 4) a single triac T1 connected to the main winding L1 is switched by the drive circuit 1. Further aspects relate to the microprocessor 3 and ring store 2. Uses include driving a pump, fan and hoist.

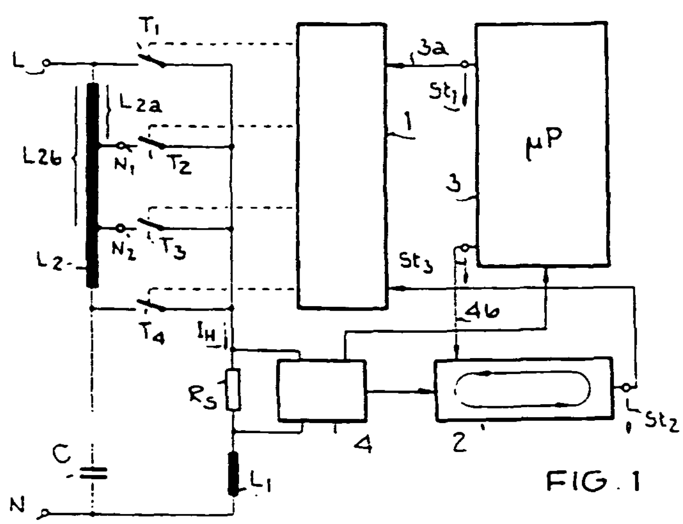

FIG. 1

GB 2 294 167 A

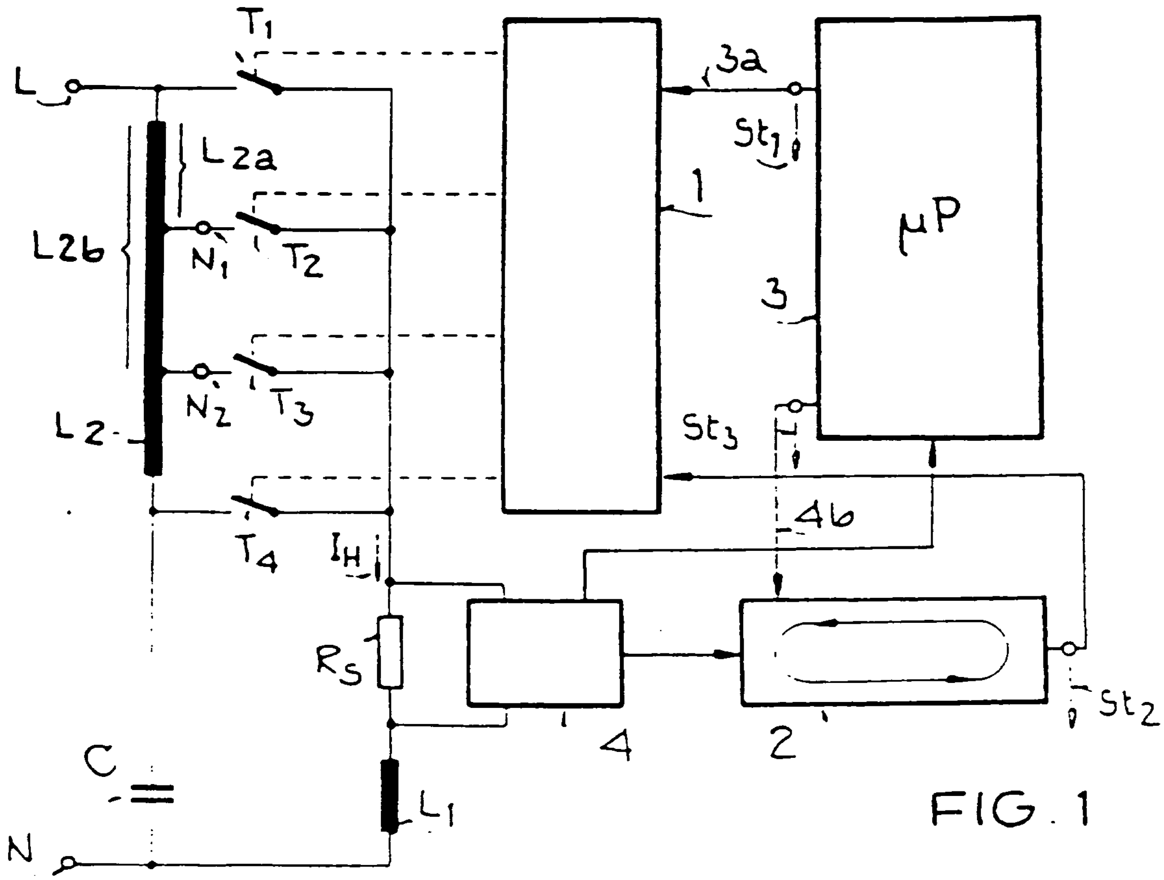
T1
L
L2a
L2b
N1
T2
N2
T3
L2
T4
IH
RS
C
N
L1
3a
St1
1
μP
3
St3
4b
4
2
St2

FIG. 1

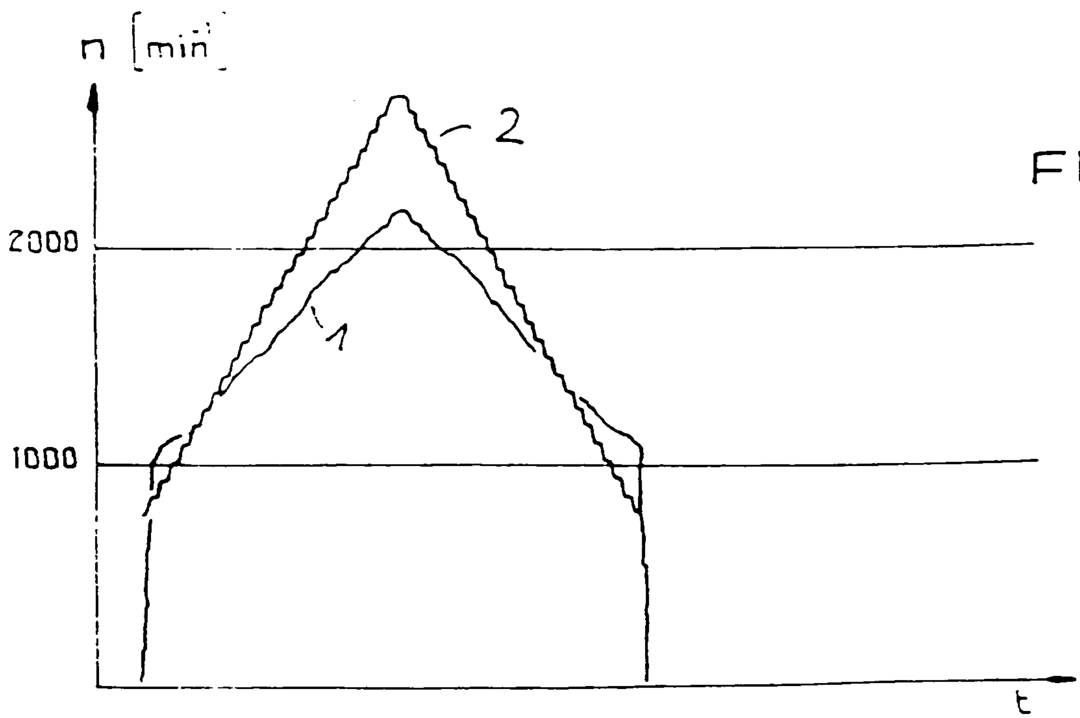
n [min]
2
2000
1
1000
t

FIG. 2

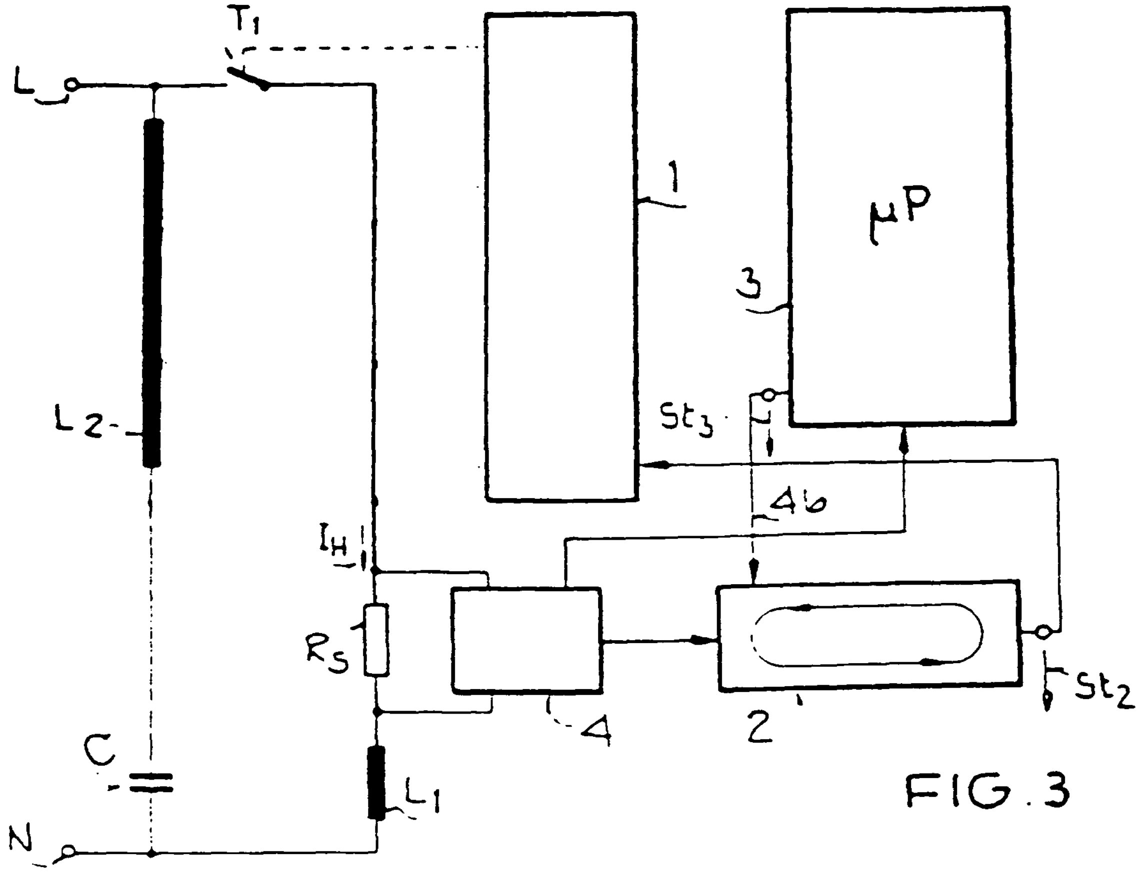
T1
L
L2
C
N
1
μP
3
St3
46
IH
RS
L1
4
2
St2

FIG. 3

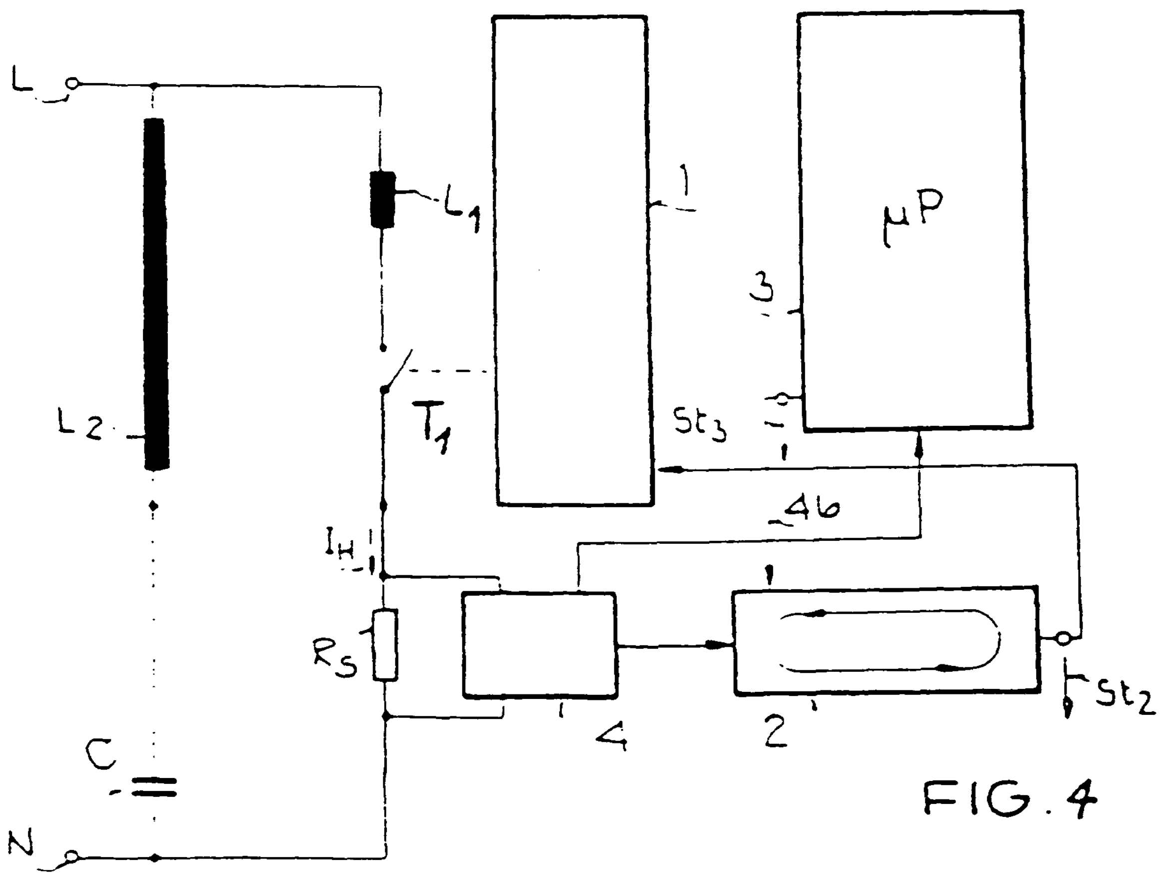
L
L1
L2
T1
C
N
1
μP
3
St3
46
IH
RS
4
2
St2

FIG. 4

A Process for the Power Control of an Induction Motor

The invention relates to a process for the power control of an induction motor run from a single-phase supply mains, in particular a capacitor motor, and a device for the implementation of this process according to the invention.

DE 36 07 162 C2 describes a capacitor motor which is run from a single-phase supply mains and wherein a first switch connects the main winding in series to the auxiliary winding and in parallel to the capacitor and a second switch connects the main winding in parallel to the series arrangement of auxiliary winding and capacitor. When this motor is switched on by the closure of the first switch, the motor runs at a low power level. If, on the other hand, the first switch is opened and the second switch is closed, the motor runs at its highest speed and thus supplies the highest power. Finally, by alternately changing over between the two switches, the motor can be set at a power output between the two aforementioned power levels. Finally, the power output by the motor can be further reduced if, with the first switch closed, and thus with the main winding connected in series to the auxiliary winding, the entire motor is connected to the supply mains in alternating fashion. The switches are driven by a switch control device in such manner that the switching processes in each case take place in the zero transition of integral periods of the alternating current. The generation of the control signals for these switches by means of the switch control device is not explained however in this document.

US 4 737 701 discloses such a capacitor motor, the auxiliary winding of which, for the formation of a plurality of sub-windings, possesses tappings which via a selector switch selectively can be connected in series with the main winding, so that these sub-windings are no longer

available as an auxiliary winding. Depending upon the position of the selector switch, different operating points can be set, leading to different speeds of the motor and thus also to different torques.

Furthermore DE 40 31 708 A1 discloses a process for the differential pressure regulation of a pump system which employs a capacitor motor of this kind known from the above mentioned publication. In order to obtain a constant differential pressure in the pump system, the tappings from the auxiliary winding are connected to the main winding of the motor as a function of an actual value.

The power control of the capacitor motor on which this regulation process is based leads however to a discontinuous regulation, the properties of which are dependent upon the number of tappings of the auxiliary winding. In order to adjust the controlled variable more precisely to a setpoint value, a large number of tappings would thus be required, leading however to too high costs of the capacitor motor.

Therefore the aim of the invention is to provide a process for the power control of an induction motor of the type referred to in the introduction run from a single-phase supply mains, with which a virtually constant regulation of a controlled variable and a virtually constant control of a control variable can be effected and furthermore in a cost-favourable manner. A device for the implementation of this process according to the invention is also to be provided.

According to a first aspect of the present invention, there is provided a process for the power control of an induction motor run from a single-phase supply mains, with a main winding and an auxiliary winding, wherein by means of a switch controllable by a drive circuit the main winding is directly connected to the single-phase supply mains,

wherein: a) for the setting of the power to be output by the induction motor a recurring digital m-bit data word is generated, b) the switch is actuated as a function of the consecutive logic values of the m-bit data word and c) the actuation of the switch is synchronised with the mains frequency.

Thus, for the setting of the power to be output by the induction motor a recurring digital (binary) m-bit data word (code word) is generated and the switch is actuated as a function of the consecutive logic values, where the actuation of said switch is synchronised with the mains frequency. Since the motor runs at its highest power level when the switch is closed and is set at its lowest power level when the switch is open, intermediate power levels can be set as a function of the m-bit data word and thus the range between the lowest and the highest power levels can be discretized, where the number of discretization stages depends upon the length of the m-bit data word. With an appropriate selection of the length m and when the time duration of a discretization stage - i.e. the time duration defined by the number of repetition cycles of a m-bit data word - is selected to be short, a virtually constant regulation or control response of the motor can be achieved.

According to a second aspect of the present invention, there is provided a process for the power control of an induction motor run from a single-phase supply mains, with a main winding and with an auxiliary winding provided with n tappings, wherein different power levels of the induction motor can be set by means of (n + 2) switches which are controllable by a drive circuit, in that in each case with a switch the auxiliary winding can be connected in series with the main winding or in each case a tapping of the auxiliary winding can be connected to the main winding or the main winding is directly connected to a phase of the

single-phase mains, wherein: a) for the coarse adjustm nt of the power to be output by the induction motor a specified power level is set by the closure of a first switch, b) for the fine adjustment of the power to be output by the induction motor a recurring digital m-bit data word is generated, c) as a function of the consecutive logic values of the m-bit data word, the first switch selected for the coarse adjustment of the power output is actuated in alternation with a second switch, where this second switch sets the next higher or the next lower power level compared to the first switch and d) the alternating actuation of the first and second switches is synchronised with the mains frequency of the single-phase mains.

In the case of the second mentioned solution, for the coarse adjustment of the power to be output by the induction motor, a specified power level is set by the activation of a first switch and at the same time for the fine adjustment of the power to be output by the induction motor a recurring digital m-bit data word is generated. As a function of the consecutive logic values of the data word, the first switch selected for the coarse adjustment of the power output is actuated in alternation with a second switch, where this second switch sets the next higher or the next lower power level compared to the first switch. Here the alternating actuation of the first and second switches is synchronised with the mains frequency.

Advantageously, with this keying of the m-bit data word according to the invention, a plurality of power levels present between two power levels can be set without the need for additional tappings from the auxiliary winding. The number of these additional power levels is dependent upon the length m of the m-bit data word. As an induction motor has large time constants, with the selection of an appropriately short time duration of a discretization stage - i.e. the time duration defined by the number of

repetition cycles of a m-bit data word - of for example 80 ms and a 8-bit data word, the process according to the invention leads to a virtually constant control response.

An idea common to both aspects is that of making available a simple and effective conversion of a setpoint value or control deviation into a control variable for the variable to be controlled or regulated, here the power to be output by the motor, where the control variable, i.e. the m-bit data word (code word), is generated as a function of the setpoint value or control deviation.

The invention also provides devices for implementation of the above processes.

Corresponding to the first aspect, a microprocessor and a ring store are provided, where the microprocessor generates the m-bit data word as a function of a setpoint value or a control deviation and supplies the latter to the ring store, and the ring store forwards the logic values of the m-bit data word successively to the drive circuit for the setting of the power to be output by the motor, so that the switch undergoes a corresponding on-off keying.

Corresponding to the second aspect, a microprocessor is provided which on the one hand, as a function of a setpoint value or a control deviation, carries out, via the drive circuit, the coarse adjustment of the power to be output by the motor and on the other hand generates the m-bit data word and supplies the latter to a ring counter. The m-bit data word is read out successively from this ring counter and for the fine adjustment of the power to be supplied by the capacitor motor likewise is supplied to the drive circuit. Here the switch which carries out the coarse adjustment is on/off-keyed in alternation with a further switch in accordance with the m-bit data word. Preferably a zero transition detector is provided for the clock

control of the ring counter.

In this way the process according to the invention can be carried out using a simple device as regulating devices which regulate the motor power of induction motors normally are provided with a microprocessor and thus only a ring counter which stores the m-bit data word is additionally required.

The co-ordination between a m-bit data word and a setpoint value is stored in a table, whereby a simple access possibility is provided. If an automatic regulating system is to be constructed, each control deviation is assigned a m-bit data word and likewise stored in a table.

In an advantageous embodiment of the invention wherein the auxiliary winding is provided with tappings, the entire auxiliary winding of the motor is connected in series with its main winding, for which reason the motor generally operates at the lowest power level. However, commencing from this power level the adjustment range can be markedly extended downwards by means of one single energization of the auxiliary winding. For this purpose the switch which sets the lowest power level must be actuated, to which end a corresponding m-bit data word, which leads to an on/off keying of this switch, is generated.

The synchronisation of the keying with the zero transition of the current can be achieved by sensing the auxiliary current, by calculation from a table stored in the microprocessor, or on the basis of the intermittent switching-on of the switch.

Preferred embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, of which:

Figure 1 is a block circuit diagram of a circuit arrangement for the implementation of the process according to the invention where the auxiliary winding possesses tappings;

Figure 2 is a time-speed diagram of a capacitor motor regulated by the process according to the invention illustrated in Figure 1; and

Figures 3 and 4 in each case represent a block circuit diagram of a further circuit arrangement for the implementation of the process according to the invention, where an auxiliary winding without tappings is used.

In Figure 1 the main winding, the auxiliary winding and a starting capacitor of a single-phase capacitor motor have been referenced L1, L2 and C. Here the series circuit comprising the capacitor C and the auxiliary winding L2 is connected to the terminals N and L of a single-phase mains which supplies the operating voltage for the induction motor. A further series circuit comprising the main winding L1, a shunt resistor R_s and a semiconductor switch T4 is connected in parallel to the starting capacitor C. The auxiliary winding L2 also comprises a first and second tapping N1 and N2 which are in each case connected via a semiconductor switch T2 and T3 to the circuit branch which connects the shunt resistor R_s to the semiconductor switch T4. For the driving of the semiconductor switches T1 to T4, which are designed as triacs, their drive electrodes are connected to a drive circuit 1 via appropriate lines.

By means of these triacs T1 to T4 the inductor motor can be set at different power levels in that, in dependence upon the triac which is switched on, the motor runs at different speeds, thereby generating different torques. Thus the capacitor motor runs at the lowest speed and thereby is set at a low power level when the triac T4 is switched on and

the entire auxiliary winding L2 is connected in series, as a choke, with the main winding. If, on the other hand, one of the two triacs T3 or T2 is switched on, a sub-winding L2b or a sub-winding L2a of the auxiliary winding L2 is connected in series with the main winding L1 so that the speed of the motor is increased in stepped fashion, with the result that two further power levels can be set. Finally the highest power level is reached when the triac T1 is switched on in that the auxiliary winding L2 is thereby bridged and the main winding L1 is directly connected to the phase L. The motor runs at its highest power level. As a result of this selective connection of the auxiliary winding and its sub-windings it is possible to set four power levels which, with a uniform operating voltage, differ from one another by virtue of different torques.

If, for example, the motor according to Figure 1 is used as a pump motor in a heating system, the pump supplies the greatest power when the main winding L1 of the motor is connected via the triac T1 to the phase L of the single-phase mains. As a result of the connection of the auxiliary winding L2a or L2b, the pump power is reduced in stepped fashion until, when the entire auxiliary winding L2 is connected, the initially lowest power level is reached. A further reduction in the power level is possible by providing that none of the four triacs T1 to T4 is switched on, with the result that only an auxiliary current is maintained through the auxiliary winding L2. With the last-mentioned possibility of setting the lowest power level, five power levels can thus be set.

To facilitate the switching of the triacs T1 to T4 in each case in the zero transition of the operating voltage of the motor, a zero point detector 4 is provided which detects the zero transitions of the current by analyzing the voltage drop across the shunt resistor R_3 and supplies said

zero transitions to a microprocessor 3.

For the driving of the triacs T1 to T4, the drive circuit 1 is supplied with a first control signal St1 generated by the microprocessor 3 and with a second control signal St2 which represents a m-bit data word. This m-bit data word is stored in a ring counter 2 and from the latter is read out successively into the drive circuit 1. The data content of this ring store 2 is likewise generated by the microprocessor 3 and input into the ring counter 2.

For the coarse adjustment of the power to be output by the motor, a specified power level is set by the first control signal St1 in that one of the triacs T1 to T4 is switched on. For the fine adjustment of the power to be output by the motor the m-bit data word now is used, which latter represents a keying pattern for the currently switched-on triac. If, for example, the triac T4 is switched on for the coarse adjustment of the power to be output, and if the motor is to emit a somewhat higher power, for example the following data word (01111111) is generated. This 8-bit data word circulates in the ring counter 2 in the cycle of the mains frequency, and more specifically in the cycle of the zero transitions of the main winding current I_H, and is read out cyclically into the drive stage 1. Here the logic "0" causes the power switch T4 to remain closed, while the logic "1" causes this power switch T4 to open and the power switch T3 to be switched on instead. In this way for the length of one cycle the entire auxiliary winding L2 is connected in series with the main winding L1 and then for the length of seven cycles only the sub-winding L2b is connected in series, as a choke, with the main winding L1, where at a mains frequency of 50 Hz the cycle length amounts to 10 ms.

The effect of the above mentioned digital word can also be defined such that with the logic "0" the switch T4 is

closed but with the logic "1" this switch is opened and with the latter all the switches T1 to T4 remain open. In contrast to the first effect of the digital word, in the case of the last mentioned effect a reduction in power is achieved which lies between the lowest power level at which all the switches T1 to T4 are open and the next higher power level at which only the switch T4 is closed. The extent of the reduction or increase in power is governed by the distribution of the logic "0"s and the logic "1"s within the data word. Thus with the aid of this data word, which occurs with a specific keying pattern of the switch selected for the coarse adjustment of the power output, the power range present between two power levels can be discretized. The discretization here is a function of the word length of the data word. With a word length of 8 bits, a number of 26 discretization stages results according to the following formula:

$$(N - 1) \cdot N_{bit} + 2$$

where N is the number of basic stages - in the present example there are 4 basic stages - and N_{bit} is the word length of the data word. Finally the "OFF"-state and the 100%-"ON"- state are to be added as further stages.

If the motor power now is to be further increased, the microprocessor 3 switches to the switch T3 so that now the next higher power level is set.

At the same time a keying pattern based on a 8-bit data word, likewise generated by the microprocessor 3, is again generated for this switch T3 so that keying is effected either with the switch T2 which is responsible for the next higher power level or with the switch T4 which is responsible for the next lower power level.

The increase in power can thus take place continuously in stepped fashion by means of the coarse adjustment and the keying patterns generated by the 8-bit data words. Here it has proved that excellent linearity is achieved as can be seen from Figure 2. Commencing from the lowest speed, which corresponds to the lowest power level, the motor is continuously adjusted up to the maximum speed corresponding to the highest power level, whereupon it is then adjusted back to the lowest speed. In Figure 2 the curve 1 represents the actual value characteristic of the speed and the curve 2 represents the setpoint value characteristic. In the case of the curve 2 the discretization stages generated by the keying pattern can easily be seen; however these are averaged out as a result of the inertia of the motor masses participating in the rotational movement so that a constant control response in accordance with curve 1 results.

The embodiments according to Figures 3 and 4 differ from the embodiment according to Figure 1 in that the auxiliary winding L2 has no tappings. In accordance with Figure 3 a switch T1 connects the main winding L1 via the shunt resistor R_s to the phase L, whereas in accordance with Figure 4 a corresponding switch T1 connects the main winding L1 via the shunt resistor R_s to the zero conductor N of the operating voltage supply. Also in the case of these two embodiments, for the driving of the switch T1 a m-bit data word generated by the microprocessor 3 is fed via a ring counter 2 to the drive unit 1, as explained in association with the embodiment according to Figure 1. As the auxiliary winding L2 has no tappings, a first control signal St1, which is required in association with the exemplary embodiment according to Figure 1, also is not required.

By appropriate selection of the m-bit data word, any power level between the lowest power level - i.e. with the switch

T1 open - and the highest power level - with the switch T1 closed - can be set.

A linear ascent to the highest power level of the motor is also possible if the logic values of the respective m-bit data word, which logic values effect the closure of the switch T1, increase successively until, in the maximum power output state, all the logic values of a m-bit data word effect the closure of the switch T1. A speed curve as illustrated in Figure 2 can be achieved in this way.

On the basis of the linear characteristic of the control process according to the invention it is possible to construct automatic regulating systems with a constant control response. Thus for example the capacitor motor shown in Figures 1, 3 or 4 can be used as a pump motor for heating systems, where the controlled variable can be the speed of the motor, the differential pressure in the closed heating system or also the room temperature. The actual value detection here can be carried out in a manner with which those skilled in the art will be familiar, for example using a tacho-generator or exclusively by the detection of electrical variables, where the microprocessor 3 derives a correcting variable from the actual value and from a setpoint value, which correcting variable leads to a specific coarse adjustment of the power output and to a corresponding keying pattern in the case of the exemplary embodiment according to Figure 1 and merely requires a m-bit data word, which latter is converted by the drive unit 1 into a corresponding on/off keying pattern for the switch T1, in the case of the exemplary embodiments according to Figures 3 and 4.

The control process according to the invention can be used in all cases where capacitor motors are employed, thus also for example for fan motors for refrigerating units or drive motors for hoisting machines.

Claims

1. A process for the power control of an induction motor run from a single-phase supply mains, with a main winding and an auxiliary winding, wherein by means of a switch controllable by a drive circuit the main winding is directly connected to the single-phase supply mains, wherein:

a) for the setting of the power to be output by the induction motor a recurring digital m-bit data word is generated,

b) the switch is actuated as a function of the consecutive logic values of the m-bit data word and

c) the actuation of the switch is synchronised with the mains frequency.

2. A process according to claim 1, wherein the motor is a capacitor motor.

3. A process for the power control of an induction motor run from a single-phase supply mains, with a main winding and with an auxiliary winding provided with n tappings, wherein different power levels of the induction motor can be set by means of (n + 2) switches which are controllable by a drive circuit, in that in each case with a switch the auxiliary winding can be connected in series with the main winding or in each case a tapping of the auxiliary winding can be connected to the main winding or the main winding is directly connected to a phase of the single-phase mains, wherein:

a) for the coarse adjustment of the power to be output by the induction motor a specified power level is set by the closure of a first switch,

b) for the fine adjustment of the power to be output by the induction motor a recurring digital m-bit data word is generated,

c) as a function of the consecutive logic values of the m-bit data word, the first switch selected for the coarse adjustment of the power output is actuated in alternation with a second switch, where this second switch sets the next higher or the next lower power level compared to the first switch and

d) the alternating actuation of the first and second switches is synchronised with the mains frequency of the single-phase mains.

4. A process according to claim 3, wherein the motor is a capacitor motor.

5. A process as claimed in Claim 3 or 4, wherein for the setting of the lowest power level only the auxiliary winding is energized, and wherein:

a) for the coarse adjustment of a low power to be output by the induction motor, the switch which switches the entire auxiliary winding is actuated and

b) the m-bit data word generated for the fine adjustment of the power to be output leads to the on/off keying of the switch as a function of the consecutive logic values of the m-bit data word.

6. A device for the implementation for the process claimed in Claim 1 or 2, wherein:

a) a microprocessor and a ring store are provided,

b) where the microprocessor generates the m-bit data word and supplies the latter to the ring store and

c) the ring store supplies the logic values of the m-bit data word successively to the drive circuit for the setting of the power to be output by the induction motor.

7. A device for the implementation of the process claimed in any of Claims 3 to 5, wherein:

a) a microprocessor and a ring store are provided,

b) the microprocessor carrying out, via the drive circuit, the coarse adjustment of the power to be output by the induction motor and also

c) generating the m-bit data word and supplying it to the ring store and

d) the ring store supplies the logic values of the m-bit data word successively to the drive circuit for the fine adjustment of the power to be output by the induction motor.

8. A device as claimed in Claim 6 or 7, wherein a zero transition detector is provided for the clock control of the ring store.

9. A process substantially as herein described with reference to Figs. 1 and 2, or Fig. 3, or Fig. 4 of the accompanying drawings.

10. A device substantially as herein described with reference to Figs. 1 and 2, or Fig. 3, or Fig. 4 of the accompanying drawings.

Patents Act 1977 16 **Examiner's report to the Comptroller under Section 17** **(The Search report)**	Application number GB 9520893.0
Relevant Technical Fields (i) UK Cl (Ed.N) H2J (JSAX, JSVP, JSVF, JSVV) (ii) Int Cl (Ed.6) H02P 7/00	Search Examiner MR B EDE Date of completion of Search 14 DECEMBER 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE: WPI	Documents considered relevant following a search in respect of Claims :- 1-5 AND 9

Categories of documents

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E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2271893 A	(PLESSEY) see 6, 10, the figure	1 and 3
X	GB 2253099 A	(HITACHI) whole document relevant	1 and 3
X	GB 2242795 A	(TOSHIBA) see 1, 5, 6, 7, Figure 2	1 and 3
X	GB 2215147 A	(HITACHI) see 2-4, 10, 107, 108, 110, Figure 1	1 and 3
X	GB 2093288 A	(HITACHI) see 12, 14, 22, Figure 1	1 and 3
X	GB 1552625	(JOHNSON & STARLEY) see 12, 34, 36, Figure 1	1 and 3

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